Technical Memorandum

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To: Mike Peebles, PE (Otak)

From: Rose Horton, PE

Copies: File

Date: June 27, 2017

Subject: The Ridge at South Cooper Mountain Multi-Family Preliminary Drainage Report

Project No.: 17849A

Introduction

The Ridge at South Cooper Mountain Multi-family development project is a proposed residential development in the City of Beaverton, with stormwater jurisdiction through Clean Water Services (CWS). The development will consist of two multifamily buildings and parking. The development also includes sidewalks, public trail, public roadways, private driveways, utilities, and a stormwater management system. The stormwater management system will include a conveyance system and regional stormwater management facility.

The memorandum outlines compliance of the Ridge at South Cooper Mountain Multi-family stormwater management system with the U.S. Army Corps of Engineers *SLOPES V for Stormwater, Transportation and Utilities* (USACOE, 2014), the City of Beaverton (COB) *Engineering Design Manual* (COB, 2007) and the Clean Water Services *Design and Construction Standards for Sanitary Sewer and Surface Water Management* (CWS, 2017). Descriptions of the pre-development and proposed hydrologic conditions, as well as documentation showing the preliminary onsite stormwater management system's compliance with SLOPES V and COB standards for water quality and quantity mitigation are included in this report.

Design Standards

Design of the proposed stormwater system will meet the following design criteria:

- *SLOPES V for Stormwater, Transportation and Utilities* (USACOE, 2014)
- *Design and Construction Standards for Sanitary Sewer and Surface Water Management* (CWS, 2017)
- *Engineering Design Manual* (COB, 2007)
- *Low Impact Development Approaches Handbook* (CWS, 2016)
- *City of Beaverton - City Engineer's Interpretation No. 06.16.17-01*

The City of Beaverton has adopted the CWS *Design and Construction Standards for Sanitary Sewer and Surface Water Management*. All City standards in the *Engineering Design Manual* meet or exceed the CWS stormwater requirements. Additionally, this project impacts wetlands, which requires stormwater management to be compliant with *SLOPES V for Stormwater Transportation and Utilities* standards. The City of Beaverton released an interpretation of SLOPES V requirements to aid in design of stormwater management facilities that are required to be in compliance with SLOPES V. The interpretation defines three possible compliance paths for calculating discharge rates to meet SLOPES V requirements and preferred modeling mechanics for demonstrating flood control of the 25-year design storm event.

Site Description

Location

The proposed Ridge at South Cooper Mountain Multi-family development is located in the City of Beaverton, Oregon. The project site is bordered to the south by SW Scholls Ferry Road, and to the west by an unnamed drainage channel with a delineated vegetated corridor (see Vicinity Map). The site is currently being used for agriculture which includes evergreen tree farm.

Vicinity Map

The 5.34-acre Ridge at South Cooper Mountain Multi-family development, including SW Scholls

Ferry frontage improvements, lies within Washington County Tax Map 2S106 Lots 500 (Bellairs property) and 600 (Lolich property).

Topography

The Ridge at South Cooper Mountain Multi-family project will be constructed on agricultural land with slopes ranging from 3 to 20 percent. Existing elevations on the property vary between approximately 290 feet on the east edge to 260 feet on the west side sloping westward toward the drainage channel.

Drainage Basins

Existing Conditions

The project site is located within the Rock Creek/Tualatin River sub-watershed (hydrologic unit code [HUC] 170900100503). The site drains to an unnamed natural drainage channel along the western boundary that flows south under SW Scholls Ferry Road (see Figure 1). The drainage channel crosses under SW Scholls Ferry Road (Hwy 210) through a 36-inch culvert and then combines with another unnamed drainage from the west into a single channel. From there, the drainage channel flows south approximately 1.3 miles before it outfalls into the Tualatin River.

The onsite drainage basin area is 5.34 acres. Existing site conditions consist of an evergreen tree farm, out buildings and access drives. Runoff from the existing drainage basin drains to the channel that runs along the west boundary of the site, which has an unmapped floodplain. A flood study performed by Otak (Otak, 2016) modeled the channel under existing conditions to determine the limits of the regulatory base flood (100-year event). The modeled floodplain limits determined from this previous study are shown on Figure 1.

It is worth noting that the term "existing conditions" refers to the project site under current land use conditions. SLOPES V standards require runoff rates for the pre-developed condition, which is the discharge rate for the site based on its natural groundcover and grade before any development occurred. Per the City of Beaverton City Engineer's Interpretation No. 06.16.17-01, the predeveloped condition of the site to be used in hydrologic calculations is woods in fair condition.

Proposed Conditions

The proposed development will consist of two multi-family residential buildings, parking, public roadway and public and private sidewalks. The project will add approximately 3.28 acres of new or redeveloped impervious area, including rooftops, roadways, sidewalks, pedestrian trail, and driveways and a total of 4.12 impervious acres including the frontage improvements of SW Scholls Ferry Road. The widening and redevelopment of SW Scholls Ferry Road will be constructed over the drainage channel along the north side of the road. The pedestrian trail adjacent to the vegetated corridor will have a gravel shoulder with an underlying perforated pipe to collect runoff from the

trail and convey it to the stormwater facility. Pervious areas will consist of lawn, shrubs, and trees.

Under proposed conditions, the site was divided into three drainage basins that will convey runoff to an extended dry detention pond. The pond was designed to meet both water quality and water quantity requirements for the project. Basin P2 includes the multi-family residential development; Q1 includes the SW Scholls Ferry Road public ROW improvements; and Q2 includes the public access road to serve the development as shown on Figure 2. See Table 1 for a summary of the basin areas under pre-development and proposed conditions.

Table 1: Basin Areas

	Pre-development Conditions			Proposed Conditions		
Basin	Impervious Area (ac)	Pervious Area (ac)	Total Area (ac)	Impervious Area (ac)	Pervious Area (ac)	Total Area (ac)
P2	0.00	4.27	4.27	3.20	1.07	4.27
Q1	0.00	0.72	0.72	0.65	0.07	0.72
Q2	0.00	0.34	0.34	0.27	0.07	0.34
Total	**0.00**	**5.34**	**5.34**	**4.12**	**1.21**	**5.34**

Hydrology

For site analysis and modeling purposes, pervious and impervious areas within the proposed development were quantified separately, as shown above in Table 1. Peak runoff rates generated from each development phase were calculated using the Santa Barbara Urban Hydrograph (SBUH) method in HydroCAD v10.0. Precipitation depths for this project site (listed in Table 2) were obtained from the COB *Engineering Design Manual*. These depths were determined to be more conservative than both the CWS and NOAA precipitation depths, and were therefore used to calculate site rainfall and runoff rates based on the NRCS Type 1A rainfall distribution.

Table 2: City of Beaverton Precipitation Depths

Recurrence Interval	Precipitation Depth (in)
2-Year	2.50
10-Year	3.50
25-Year	4.00
100-Year	4.50

Soils

Soils are categorized by the National Resource Conservation Service (NRCS) as hydrologic soil group (HSG) types C and D, which consist of Cascade and Delena silt loams (See Appendix A). These soils generally exhibit moderate to low infiltration rates and relatively high runoff rates. The site is almost entirely Type C soils within the area of proposed development, while Type D soil is shown to be present within stream and wetland corridor limits to the west.

Curve Number

Curve Numbers (CN) for impervious and pervious areas during pre-development and proposed conditions were selected using Table 2.2 – Runoff Curve Numbers for Selected Agricultural, Suburban, and Urban Areas (WSDOE, 2005) (See Appendix A).

SLOPES V requires release rates from detention facilities to match the frequency and duration of flows generated by storms on the pre-development site conditions. As such, the project site is modeled using CNs under pre-development conditions for establishing target flow rates, and CNs reflective of new development for calculating future runoff rates. Table 3 provides a summary of the runoff curve numbers under pre-development and proposed conditions.

Table 3: Runoff Curve Numbers

Category	Cover Type	Hydrologic Soil Group	Curve Number
Pervious Area, Pre-development Conditions	Woods - Fair Condition	C	73
Pervious Area, Pre-development Conditions	Woods - Fair Condition	D	79
Pervious Area, Proposed Conditions	50-75% Grass cover - Fair Condition	C	90
Pervious Area, Proposed Conditions	50-75% Grass cover - Fair Condition	D	92
Impervious Area	Pavement, roofs, sidewalks	C/D	98

Time of Concentration

The time of concentration (Tc) represents the maximum time needed for all areas of the basin to contribute to the outflow hydrograph. A time of concentration value for the drainage basin during existing conditions was calculated using the method provided by the SCS Technical Release 55 (SCS, 1986) (see Appendix A). Per the City of Beaverton City Engineer's Interpretation No. 06.16.17-01, time of concentration used for calculating flows to show SLOPES V compliance should be based on the site's pre-developed condition. Time of concentration used for calculating flow rate targets for the 25-yr flood control event may use the site existing conditions as pre-developed conditions.

The time of concentration calculated for pre-developed conditions was used to calculate flow rates for all target conditions for the sake of consistency. A time of concentration of five minutes (the minimum allowable) was applied to all proposed conditions runoff calculations as a conservative design approach.

Water Quality

SLOPES V requires water quality treatment of the runoff volume determined by multiplying 50 percent of the 2-year, 24-hour precipitation depth (2.50 inches) by the entire contributing impervious area for each drainage basin. COB standards require water quality treatment for runoff from contributing impervious areas in each drainage basin generated by 0.36 inches of precipitation falling in a 4-hour period. The requirements of SLOPES V are more conservative than the COB standards, and therefore the extended dry detention pond has been sized to treat the water quality volume generated by basins P2, Q1, and Q2 for compliance with SLOPES V requirements.

The extended dry detention pond has been designed to detain 0.7 acre-feet with a low flow orifice. This volume provided exceeds the 0.4 acre-feet required for the water quality event defined by SLOPES V. The low flow orifice detains the water quality volume to allow the settlement of pollutants. See Appendix B for water quality treatment sizing calculations for the onsite extended dry detention pond.

Water Quantity

SLOPES V Detention Requirements

SLOPES V requires flow duration matching for storm event frequencies between 50 percent of the 2-year storm event through the 10-year storm event. The City of Beaverton City Engineer's Interpretation No. 06.16.17-01, outlines three approvable methodologies/software to show compliance with SLOPES V. Two of the methodologies utilize flow duration matching tools. The third methodology, which was used for this project, is single event approximation using SBUH methodology for target peak flow matching as follows:

- Limit the proposed condition peak flow rate from the 2-year, 24-hour design storm to the pre-developed condition (woods) peak flow rate from 42% the 2-year, 24-hour design storm.
- Limit the proposed condition peak flow rate from the 10-year, 24-hour design storm to the pre-developed condition (woods) peak flow rate from the 10-year, 24-hour design storm.
- Limit the proposed condition peak flow rate from the 25-year, 24-hour design storm to the pre-developed condition (existing) peak flow rate from the 25-year, 24-hour design storm.

The proposed stormwater facility in has been sized to meet detention requirements for compliance

with SLOPES V using HydroCAD v10.0 software (see Appendix C). Table 4 provides the pre-development peak runoff rates and the detained peak discharge rates under proposed conditions the basin within the Ridge at South Cooper Mountain Multi-family project site.

Table 4: Facility Flow Control Summary				
	Peak Flow Rate (cfs)			
Site Condition	42% of 2-year	2-year	10-year	25-year
Pre-Development	0.10	0.23	0.68	0.96
Proposed (Undetained)	N/A	2.83	4.13	4.78
Proposed (Detained)	N/A	0.10	0.66	0.95

The constructed pond will be 6.65-ft deep including 1-foot of freeboard above the 25-year water surface elevation (WSE). The top surface area of the facility is 10,934 sf and the active volume storage is 34,838 cf. The active volume storage does not include the 1-foot of freeboard or the 0.4-foot of dead storage at the bottom of the pond below the outfall elevation.

Conveyance

Preliminary pipe layouts are shown in Figure 2. SLOPES V does not include pipe conveyance design criteria, therefore inlets, manholes, and pipes were located based on COB design criteria and the proposed layout of parking lots, roadways, and topography. During final design, the stormwater conveyance network will be sized using the 25-year, 24-hour storm event with the condition that the hydraulic grade line remains at least 1-foot below the rim elevations at manholes and catch basins. The conveyance outfalls into the pond will be armored to protect the channel banks.

Operations and Maintenance

An Operations and Maintenance Plan will be compiled during final design for the use of the private property owner and responsible party. The plan will identify the responsible party, describe the stormwater management system, provide information on inspecting and maintaining the extended dry basins and the water quality and flow control manholes, and include inspection logs. The inspection log will be kept onsite and made available for audit. In accordance with SLOPES V, inspection and maintenance will be required at least quarterly for the first three years, at least twice per year thereafter, and within 48 hours of a storm event greater than or equal to 1.0 inch of rain during a 24-hour period. The Operations and Maintenance Plan will be included with the Final Stormwater Management Plan.

Conclusions

The proposed Ridge at South Cooper Mountain Multi-family development project will include a stormwater management system designed to meet the requirements of SLOPES V and the City of Beaverton. The development will create approximately 4.12 acres of new impervious area. Water quality and quantity requirements will be met using a single proposed extended dry detention pond located within the project limits. The onsite conveyance system will be sized during the final design phase using standards set by the City of Beaverton.

References

COB, 2007. City of Beaverton Engineering Design Manual and Standard Drawings, City of Beaverton, January 2007.

CWS, 2017. Design and Construction Standards for Sanitary Sewer and Surface Water Management, Clean Water Services, March 2017.

CWS, 2016. Low Impact Development Approaches Handbook, Clean Water Services, July 2009.

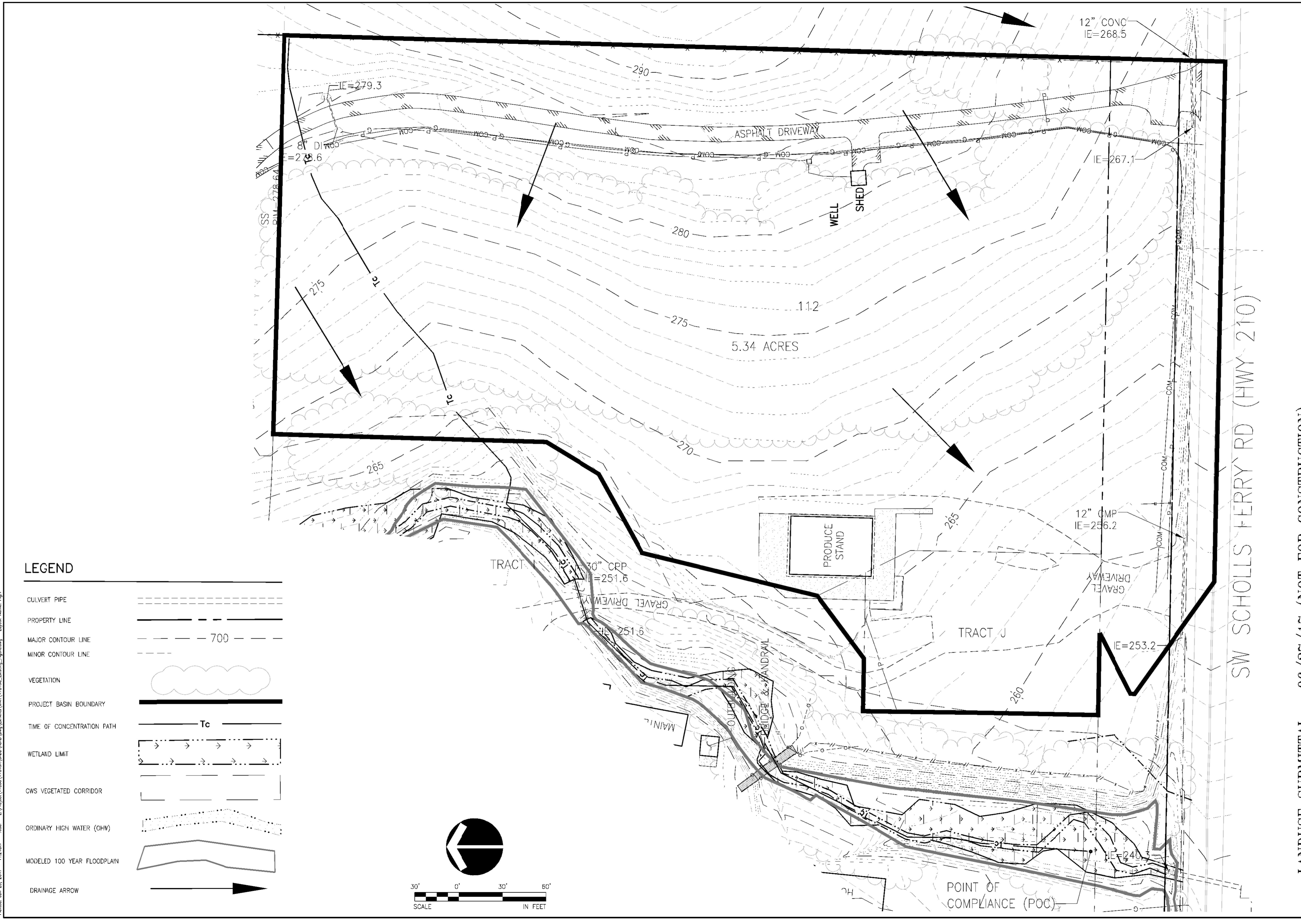
Otak, 2016. Lolich and Bellairs Existing Drainages Technical Memorandum, January 4, 2016.

SCS, 1986. Technical Release 55: Urban Hydrology for Small Watersheds, United States Department of Agriculture Soil Conservation Service, June 1986.

USACE, 2014. *SLOPES V for Stormwater, Transportation or Utilities*, United States Army Corps of Engineers, March 14, 2014.

WSDOE, 2005. *Stormwater Management in Western Washington*, Washington State Department of Ecology, February 2005.

Figures



LANDUSE SUBMITTAL – 06/27/17 (NOT FOR CONSTRUCTION)

NO.	DATE	BY	REVISION COMMENTS

Design	Drawn	Checked	Date	Initial Issue Date:
RDS	MH	MAP		

WEST HILLS DEVELOPMENT, INC.

THE RIDGE AT SOUTH COOPER MOUNTAIN

BEAVERTON, OREGON
MULTI-FAMILY
PLANNING
EXISTING CONDITIONS

otak

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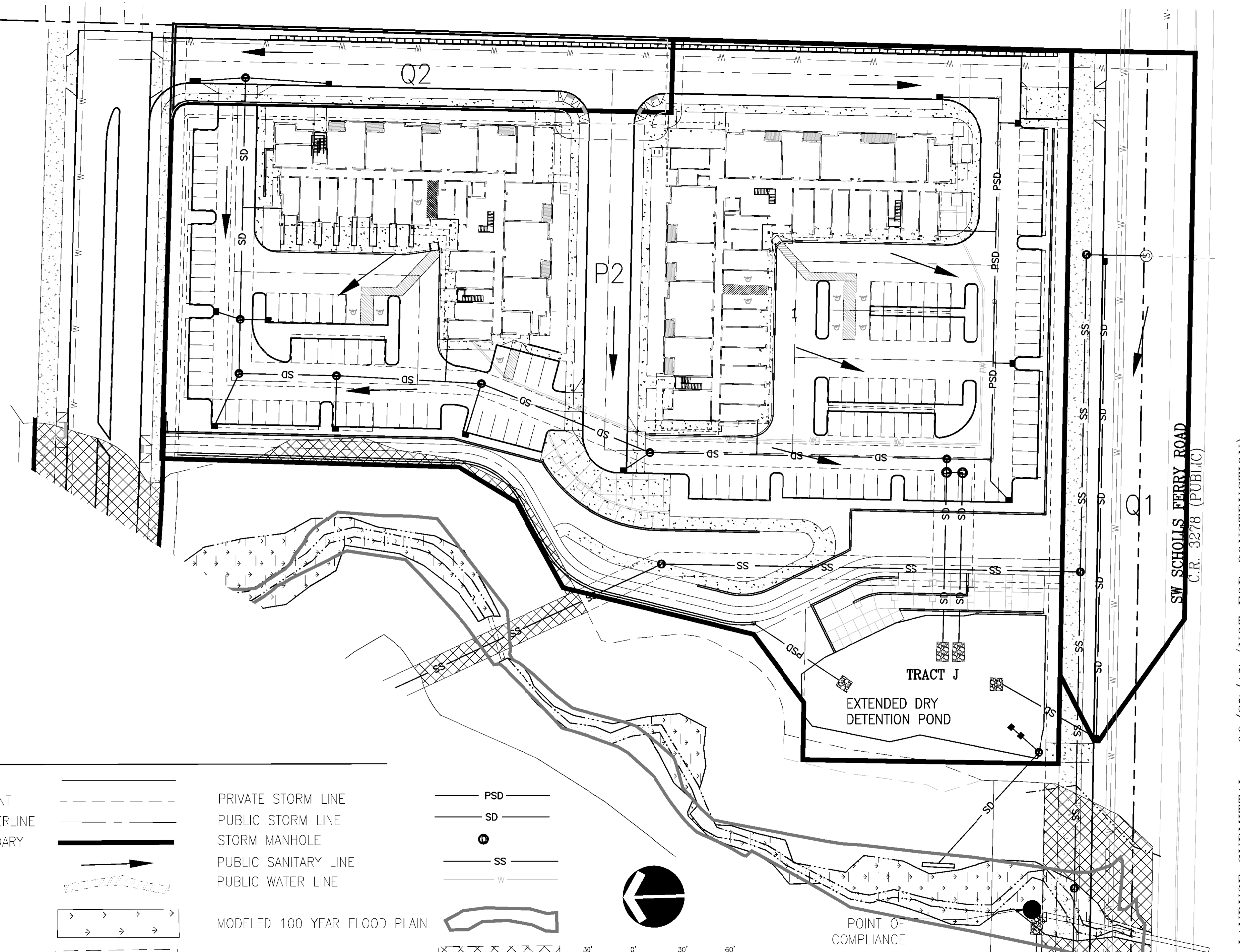
Datum: NGVD 29

17849A 17849a_Existing_Fig
Project No. Drawing No.

Fig.1
Sheet No.



LEGEND

PROPERTY LINE		PRIVATE STORM LINE	PSD
PUBLIC UTILITY EASEMENT		PUBLIC STORM LINE	SD
PROPOSED ROAD CENTERLINE		STORM MANHOLE	
DRAINAGE BASIN BOUNDARY		PUBLIC SANITARY LINE	SS
DRAINAGE ARROW		PUBLIC WATER LINE	W
ORDINARY HIGH WATER			
WETLAND LIMIT		MODELED 100 YEAR FLOOD PLAIN	
CWS VEGETATED CORRIDOR		VEGETATED CORRIDOR IMPACTS	

30' 0' 30' 60'
SCALE IN FEET

NO.	DATE	BY	REVISION COMMENTS

Design	Drawn	Checked	Date	Initial Issue Date:
BDS	MDH	MAP		

WEST HILLS DEVELOPMENT, INC.

LANDUSE SUBMITTAL - 06/27/17 (NOT FOR CONSTRUCTION)

THE RIDGE AT SOUTH COOPER MOUNTAIN

BEAVERTON, OREGON
MULTI-FAMILY
PLANNING
PROPOSED CONDITIONS

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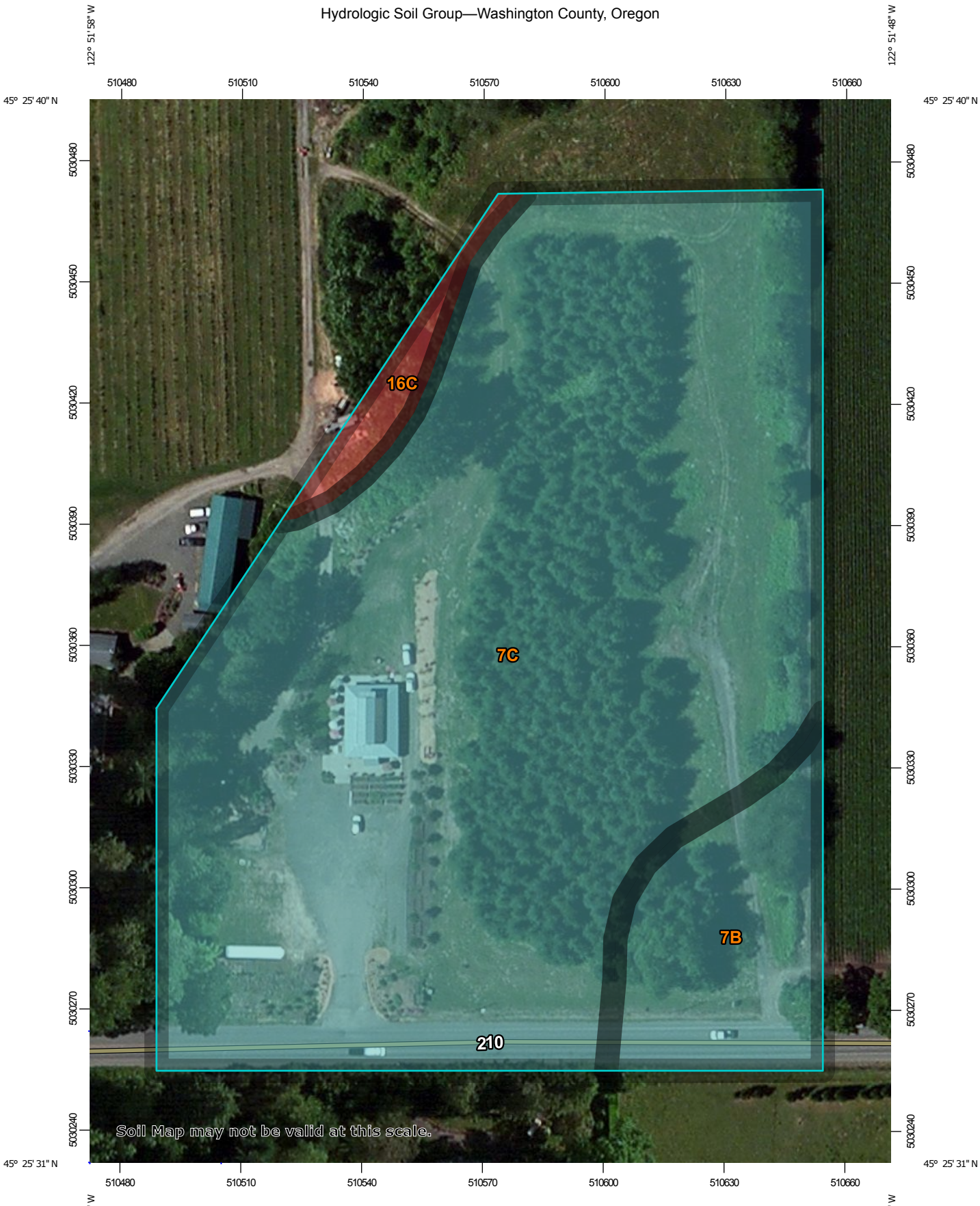
Datum: NGVD 29

17849A 17849a_Proposed_F
Project No. Drawing No.

Fig.2
Sheet No.

Appendix A—Hydrologic Information



Map Scale: 1:1,280 if printed on A portrait (8.5" x 11") sheet.

N

Meters: 0 15 30 60 90

Feet: 0 50 100 200 300

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 10N WGS84

MAP LEGEND

Area of Interest (AOI)

Area of Interest (AOI)

Soils

Soil Rating Polygons

A

A/D

B

B/D

C

C/D

D

Not rated or not available

Soil Rating Lines

A

A/D

B

B/D

C

C/D

D

Not rated or not available

Soil Rating Points

A

A/D

B

B/D

C

C/D

D

Not rated or not available

Water Features

Streams and Canals

Transportation

Rails

Interstate Highways

US Routes

Major Roads

Local Roads

Background

Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:20,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Washington County, Oregon
Survey Area Data: Version 14, Sep 16, 2016

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Jul 8, 2010—Sep 4, 2011

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Hydrologic Soil Group

Hydrologic Soil Group— Summary by Map Unit — Washington County, Oregon (OR067)				
Map unit symbol	**Map unit name**	**Rating**	**Acres in AOI**	**Percent of AOI**
7B	Cascade silt loam, 3 to 7 percent slopes	C	0.8	10.9%
7C	Cascade silt loam, 7 to 12 percent slopes	C	6.6	86.5%
16C	Delena silt loam, 3 to 12 percent slopes	D	0.2	2.6%
Totals for Area of Interest			**7.6**	**100.0%**

Description

Hydrologic soil groups are based on estimates of runoff potential. Soils are assigned to one of four groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms.

The soils in the United States are assigned to four groups (A, B, C, and D) and three dual classes (A/D, B/D, and C/D). The groups are defined as follows:

Group A. Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission.

Group B. Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.

Group C. Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.

Group D. Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

If a soil is assigned to a dual hydrologic group (A/D, B/D, or C/D), the first letter is for drained areas and the second is for undrained areas. Only the soils that in their natural condition are in group D are assigned to dual classes.

Basin Areas

17849A The Ridge at South Cooper Mountain - Multi-family

Predevelopment Drainage Basins

	Impervious Area					Pervious Area HSG C		Pervious Area HSG D		Total Area	
Basin Name	Sidewalk (sf)	Roadway (sf)	Roof (sf)	Total (sf)	Total (ac)	(sf)	(ac)	(sf)	(ac)	(sf)	(ac)
Predeveloped	0	0	0	0	0.00	232,064	5.33	365	0.01	232,429	5.34
Subtotal	**0**	**0**	**0**	**0**	**0.00**	**232,064**	**5.327**	**365**	**0.008**	**232,429**	**5.34**

Basin Areas

17849A The Ridge at South Cooper Mountain - Multi-family

Proposed Drainage Basins (Public and Private):

	Impervious Area							Pervious Area HSG C		Pervious Area HSG D		Total Area	
Basin Name	Public Sidewalk (sf)	Public Roadway (sf)	Private Sidewalk (sf)	Private Roadway (sf)	Private Roof (sf)	Total (sf)	Total (ac)	(sf)	(ac)	(sf)	(ac)	(sf)	(ac)
Q1	5,896	22,540	0	0	0	28,436	0.65	3,020	0.07	0	0.00	31,456	0.72
Q2	1,743	9,940	0	0	0	11,683	0.27	3,095	0.07	0	0.00	14,778	0.34
P2	10,159	0	11,749	66,585	50,911	139,404	3.20	46,615	1.07	176	0.004	186,195	4.27
Pond Total	**17,798**	**32,480**	**11,749**	**66,585**	**50,911**	**179,523**	**4.12**	**52,730**	**1.21**	**176**	**0.00**	**232,429**	**5.34**

Time of Concentration Calculations

Project Name: The Ridge at South Cooper Mountain MF			By: RCH	Date: 6/20/17
Project Number: 17849a			Check:	
BASINS		**Predeveloped Basin - Flood Control**	**Predeveloped Basin - SLOPES V**	
SHEET FLOW				
INPUT		(For Reference Only)		
Surface Description (from Table 3-1)		Dense Grass	Woods Fair	
Manning's Roughness Coefficient		0.24	0.4	
Flow Length , L (<300 ft)	ft	300	300	
2-Year, 24-Hour Rainfall, P_2	in	2.5	2.5	
Land Slope, s	ft/ft	0.060	0.060	
OUTPUT				
Travel Time	hr	0.42	0.63	
SHALLOW CONCENTRATED FLOW				
INPUT				
Surface Description		High Grass	Brushy	
Flow Length, L	ft	67	67	
Watercourse Slope, s	ft/ft	0.179	0.179	
OUTPUT				
Average Velocity, V	ft/s	3.81	2.12	
Travel Time	hr	0.00	0.01	
CHANNEL FLOW				
INPUT				
Cross Sectional Flow Area, a	ft^2	8.0	8.0	
Wetted Perimeter, p_w	ft	8	8	
Channel Slope, s	ft/ft	0.028	0.028	
Manning's Roughness Coefficient		0.08	0.08	
Flow Length, L	ft	470	470	
OUTPUT				
Average Velocity, V	ft/s	3.19	3.19	
Hydraulic Radius, r = a/p_w	ft	1.04	1.04	
Travel Time	hr	0.04	0.04	
Basin Time of Concentration, T_c	**hrs**	**0.46**	**0.68**	
	min	**27.8**	**40.7**	

Appendix B—Water Quality Calculations

Water Quality Calculations

17849A The Ridge at South Cooper Mountain - Multi-family

Impervious Area:

IA	4.12	ac	Proposed Impervious Area (IA)
	179,523	ft^2	

SLOPES V Standards

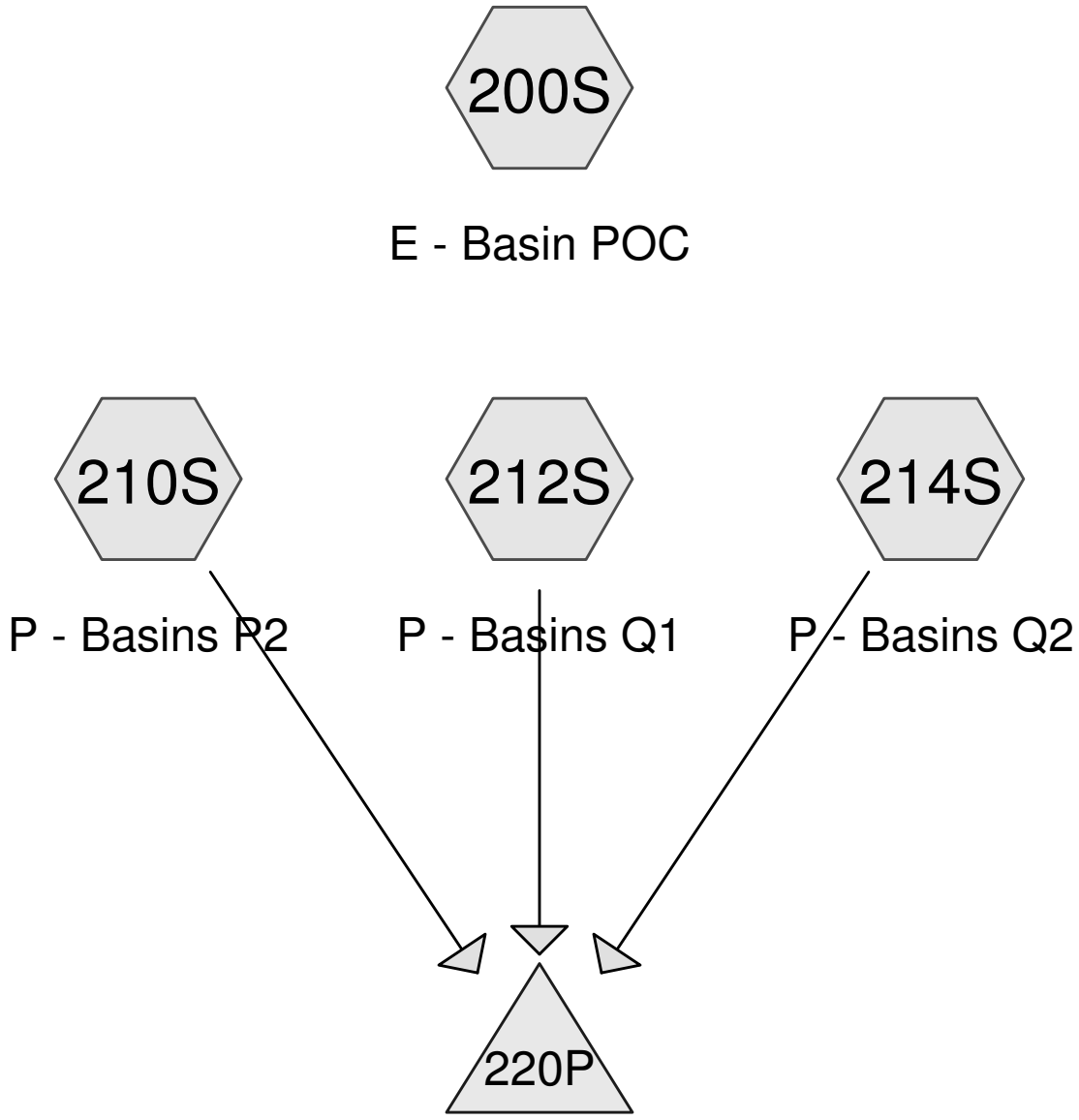
$$WQV = (1.25\ inch)\left(\frac{1\ ft}{12\ inch}\right)(Proposed\ Impervious\ Area, ft^2)$$

WQV	18,700	ft^3	Water Quality Volume
WQF	1.30	ft^3/s	Water Quality Flow

Elevation (ft)	Depth (ft)	Area (sf)	Area (ac)	Volume (cf)	
247.00	-2.00	5.1984	0.0001	0	WQ Orifice Invert*
248.99	-0.01	5.1984	0.0001	0	
249	0.00	**3,256**	**0.0747**	0	Bottom of Pond
249.01	0.01	**3,265**	**0.0750**	**33**	
250	1.00	**4,194**	**0.0963**	**3,725**	
251	2.00	**5,185**	**0.1190**	**8,415**	
252	3.00	**6,264**	**0.1438**	**14,139**	
252.68	3.68	**7,062**	**0.1621**	**18,700**	WQV
253	4.00	**7,430**	**0.1706**	**20,986**	
254	5.00	**8,685**	**0.1994**	**29,044**	
254.50	5.50	**9,355**	**0.2147**	**33,554**	2-Year Max WSE
254.64	5.64	**9,539**	**0.2190**	**34,875**	25-Year Max WSE
255	6.00	**10,028**	**0.2302**	**38,400**	
255.65	6.65	**10,934**	**0.2510**	**45,213**	Top of Pond

*The orifice is submerged (24-inches below FC outlet) and thereby controlled by the FC outlet IE

Appendix C—Water Quantity Calculations



Subcat Reach Pond Link

Routing Diagram for 17849a PrelimDetention
Prepared by Otak, Inc., Printed 6/23/2017

Summary for Subcatchment 200S: E - Basin POC

Runoff = 0.23 cfs @ 8.99 hrs, Volume= 0.252 af, Depth= 0.57"

Runoff by SBUH method, Split Pervious/Imperv., Time Span= 0.00-96.00 hrs, dt= 0.05 hrs
Type IA 24-hr 2-year Storm Rainfall=2.50"

Area (ac)	CN	Description
5.327	73	Woods, Fair, HSG C
0.008	79	Woods, Fair, HSG D
5.335	73	Weighted Average
5.335		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
40.7					**Direct Entry, Direct**

Summary for Subcatchment 210S: P - Basins P2

Runoff = 2.25 cfs @ 7.91 hrs, Volume= 0.743 af, Depth= 2.08"

Runoff by SBUH method, Split Pervious/Imperv., Time Span= 0.00-96.00 hrs, dt= 0.05 hrs
Type IA 24-hr 2-year Storm Rainfall=2.50"

	Area (ac)	CN	Description
*	3.200	98	Paved roads w/curbs & sewers, HSG C
*	1.070	90	50-75% Grass cover, Fair, HSG C
*	0.004	92	50-75% Grass cover, Fair, HSG D
	4.274	96	Weighted Average
	1.074		25.13% Pervious Area
	3.200		74.87% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.0					**Direct Entry, Direct**

Summary for Subcatchment 212S: P - Basins Q1

Runoff = 0.40 cfs @ 7.90 hrs, Volume= 0.132 af, Depth= 2.20"

Runoff by SBUH method, Split Pervious/Imperv., Time Span= 0.00-96.00 hrs, dt= 0.05 hrs
Type IA 24-hr 2-year Storm Rainfall=2.50"

	Area (ac)	CN	Description
	0.650	98	Paved roads w/curbs & sewers, HSG C
*	0.070	90	50-75% Grass cover, Fair, HSG C
	0.720	97	Weighted Average
	0.070		9.72% Pervious Area
	0.650		90.28% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.0					**Direct Entry, Direct**

Summary for Subcatchment 214S: P - Basins Q2

Runoff = 0.18 cfs @ 7.91 hrs, Volume= 0.060 af, Depth= 2.12"

Runoff by SBUH method, Split Pervious/Imperv., Time Span= 0.00-96.00 hrs, dt= 0.05 hrs
Type IA 24-hr 2-year Storm Rainfall=2.50"

	Area (ac)	CN	Description
	0.270	98	Paved roads w/curbs & sewers, HSG C
*	0.070	90	50-75% Grass cover, Fair, HSG C
	0.340	96	Weighted Average
	0.070		20.59% Pervious Area
	0.270		79.41% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.0					**Direct Entry, Direct**

Summary for Pond 220P: P - Pond

Inflow Area = 5.334 ac, 77.24% Impervious, Inflow Depth = 2.10" for 2-year Storm event
Inflow = 2.83 cfs @ 7.91 hrs, Volume= 0.935 af
Outflow = 0.10 cfs @ 24.11 hrs, Volume= 0.708 af, Atten= 96%, Lag= 971.8 min
Primary = 0.10 cfs @ 24.11 hrs, Volume= 0.708 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-96.00 hrs, dt= 0.05 hrs / 3
Peak Elev= 254.50' @ 24.11 hrs Surf.Area= 9,355 sf Storage= 33,542 cf

Plug-Flow detention time= 2,351.6 min calculated for 0.708 af (76% of inflow)
Center-of-Mass det. time= 2,196.6 min (2,886.0 - 689.4)

Volume	Invert	Avail.Storage	Storage Description
#1	249.00'	45,213 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
249.00	3,256	0	0
250.00	4,194	3,725	3,725
251.00	5,185	4,690	8,415
252.00	6,264	5,725	14,139
253.00	7,430	6,847	20,986
254.00	8,685	8,058	29,044
255.00	10,028	9,357	38,400
255.65	10,934	6,813	45,213

Device	Routing	Invert	Outlet Devices
#1	Primary	247.00'	**12.0" Round Culvert**
			L= 100.0' RCP, square edge headwall, Ke= 0.500
			Inlet / Outlet Invert= 247.00' / 245.00' S= 0.0200 '/' Cc= 0.900
			n= 0.013, Flow Area= 0.79 sf
#2	Device 1	247.00'	**1.2" Vert. WQ Orifice** C= 0.600
#3	Device 1	254.50'	**6.0' long x 0.5' breadth Broad-Crested Rectangular Weir**
			Head (feet) 0.20 0.40 0.60 0.80 1.00
			Coef. (English) 2.80 2.92 3.08 3.30 3.32
#4	Device 1	255.50'	**6.0' long x 0.5' breadth OF Weir**
			Head (feet) 0.20 0.40 0.60 0.80 1.00
			Coef. (English) 2.80 2.92 3.08 3.30 3.32

Primary OutFlow Max=0.10 cfs @ 24.11 hrs HW=254.50' (Free Discharge)
└─**1=Culvert** (Passes 0.10 cfs of 8.53 cfs potential flow)
  ├─**2=WQ Orifice** (Orifice Controls 0.10 cfs @ 13.14 fps)
  ├─**3=Broad-Crested Rectangular Weir** (Controls 0.00 cfs)
  └─**4=OF Weir** (Controls 0.00 cfs)

Summary for Subcatchment 200S: E - Basin POC

Runoff = 0.68 cfs @ 8.29 hrs, Volume= 0.524 af, Depth= 1.18"

Runoff by SBUH method, Split Pervious/Imperv., Time Span= 0.00-96.00 hrs, dt= 0.05 hrs
Type IA 24-hr 10-year Storm Rainfall=3.50"

Area (ac)	CN	Description
5.327	73	Woods, Fair, HSG C
0.008	79	Woods, Fair, HSG D
5.335	73	Weighted Average
5.335		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
40.7					**Direct Entry, Direct**

Summary for Subcatchment 210S: P - Basins P2

Runoff = 3.29 cfs @ 7.91 hrs, Volume= 1.090 af, Depth= 3.06"

Runoff by SBUH method, Split Pervious/Imperv., Time Span= 0.00-96.00 hrs, dt= 0.05 hrs
Type IA 24-hr 10-year Storm Rainfall=3.50"

	Area (ac)	CN	Description
*	3.200	98	Paved roads w/curbs & sewers, HSG C
*	1.070	90	50-75% Grass cover, Fair, HSG C
*	0.004	92	50-75% Grass cover, Fair, HSG D
	4.274	96	Weighted Average
	1.074		25.13% Pervious Area
	3.200		74.87% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.0					**Direct Entry, Direct**

Summary for Subcatchment 212S: P - Basins Q1

Runoff = 0.58 cfs @ 7.90 hrs, Volume= 0.191 af, Depth= 3.19"

Runoff by SBUH method, Split Pervious/Imperv., Time Span= 0.00-96.00 hrs, dt= 0.05 hrs
Type IA 24-hr 10-year Storm Rainfall=3.50"

	Area (ac)	CN	Description
	0.650	98	Paved roads w/curbs & sewers, HSG C
*	0.070	90	50-75% Grass cover, Fair, HSG C
	0.720	97	Weighted Average
	0.070		9.72% Pervious Area
	0.650		90.28% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.0					**Direct Entry, Direct**

Summary for Subcatchment 214S: P - Basins Q2

Runoff = 0.26 cfs @ 7.90 hrs, Volume= 0.088 af, Depth= 3.10"

Runoff by SBUH method, Split Pervious/Imperv., Time Span= 0.00-96.00 hrs, dt= 0.05 hrs
Type IA 24-hr 10-year Storm Rainfall=3.50"

	Area (ac)	CN	Description
	0.270	98	Paved roads w/curbs & sewers, HSG C
*	0.070	90	50-75% Grass cover, Fair, HSG C
	0.340	96	Weighted Average
	0.070		20.59% Pervious Area
	0.270		79.41% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.0					**Direct Entry, Direct**

Summary for Pond 220P: P - Pond

Inflow Area = 5.334 ac, 77.24% Impervious, Inflow Depth = 3.08" for 10-year Storm event
Inflow = 4.13 cfs @ 7.91 hrs, Volume= 1.369 af
Outflow = 0.66 cfs @ 13.35 hrs, Volume= 1.137 af, Atten= 84%, Lag= 326.7 min
Primary = 0.66 cfs @ 13.35 hrs, Volume= 1.137 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-96.00 hrs, dt= 0.05 hrs / 3
Peak Elev= 254.60' @ 13.35 hrs Surf.Area= 9,494 sf Storage= 34,522 cf

Plug-Flow detention time= 1,629.8 min calculated for 1.137 af (83% of inflow)
Center-of-Mass det. time= 1,515.0 min (2,193.1 - 678.1)

Volume	Invert	Avail.Storage	Storage Description
#1	249.00'	45,213 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
249.00	3,256	0	0
250.00	4,194	3,725	3,725
251.00	5,185	4,690	8,415
252.00	6,264	5,725	14,139
253.00	7,430	6,847	20,986
254.00	8,685	8,058	29,044
255.00	10,028	9,357	38,400
255.65	10,934	6,813	45,213

Device	Routing	Invert	Outlet Devices
#1	Primary	247.00'	**12.0" Round Culvert**
			L= 100.0' RCP, square edge headwall, Ke= 0.500
			Inlet / Outlet Invert= 247.00' / 245.00' S= 0.0200 '/' Cc= 0.900
			n= 0.013, Flow Area= 0.79 sf
#2	Device 1	247.00'	**1.2" Vert. WQ Orifice** C= 0.600
#3	Device 1	254.50'	**6.0' long x 0.5' breadth Broad-Crested Rectangular Weir**
			Head (feet) 0.20 0.40 0.60 0.80 1.00
			Coef. (English) 2.80 2.92 3.08 3.30 3.32
#4	Device 1	255.50'	**6.0' long x 0.5' breadth OF Weir**
			Head (feet) 0.20 0.40 0.60 0.80 1.00
			Coef. (English) 2.80 2.92 3.08 3.30 3.32

Primary OutFlow Max=0.66 cfs @ 13.35 hrs HW=254.60' (Free Discharge)
└─**1=Culvert** (Passes 0.66 cfs of 8.58 cfs potential flow)
  ├─**2=WQ Orifice** (Orifice Controls 0.10 cfs @ 13.23 fps)
  ├─**3=Broad-Crested Rectangular Weir** (Weir Controls 0.55 cfs @ 0.90 fps)
  └─**4=OF Weir** (Controls 0.00 cfs)

Summary for Subcatchment 200S: E - Basin POC

Runoff = 0.96 cfs @ 8.24 hrs, Volume= 0.679 af, Depth= 1.53"

Runoff by SBUH method, Split Pervious/Imperv., Time Span= 0.00-96.00 hrs, dt= 0.05 hrs
Type IA 24-hr 25-year Storm Rainfall=4.00"

Area (ac)	CN	Description
5.327	73	Woods, Fair, HSG C
0.008	79	Woods, Fair, HSG D
5.335	73	Weighted Average
5.335		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
40.7					**Direct Entry, Direct**

Summary for Subcatchment 210S: P - Basins P2

Runoff = 3.81 cfs @ 7.90 hrs, Volume= 1.265 af, Depth= 3.55"

Runoff by SBUH method, Split Pervious/Imperv., Time Span= 0.00-96.00 hrs, dt= 0.05 hrs
Type IA 24-hr 25-year Storm Rainfall=4.00"

	Area (ac)	CN	Description
*	3.200	98	Paved roads w/curbs & sewers, HSG C
*	1.070	90	50-75% Grass cover, Fair, HSG C
*	0.004	92	50-75% Grass cover, Fair, HSG D
	4.274	96	Weighted Average
	1.074		25.13% Pervious Area
	3.200		74.87% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.0					**Direct Entry, Direct**

Summary for Subcatchment 212S: P - Basins Q1

Runoff = 0.66 cfs @ 7.90 hrs, Volume= 0.221 af, Depth= 3.68"

Runoff by SBUH method, Split Pervious/Imperv., Time Span= 0.00-96.00 hrs, dt= 0.05 hrs
Type IA 24-hr 25-year Storm Rainfall=4.00"

	Area (ac)	CN	Description
	0.650	98	Paved roads w/curbs & sewers, HSG C
*	0.070	90	50-75% Grass cover, Fair, HSG C
	0.720	97	Weighted Average
	0.070		9.72% Pervious Area
	0.650		90.28% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.0					**Direct Entry, Direct**

Summary for Subcatchment 214S: P - Basins Q2

Runoff = 0.31 cfs @ 7.90 hrs, Volume= 0.102 af, Depth= 3.59"

Runoff by SBUH method, Split Pervious/Imperv., Time Span= 0.00-96.00 hrs, dt= 0.05 hrs
Type IA 24-hr 25-year Storm Rainfall=4.00"

	Area (ac)	CN	Description
	0.270	98	Paved roads w/curbs & sewers, HSG C
*	0.070	90	50-75% Grass cover, Fair, HSG C
	0.340	96	Weighted Average
	0.070		20.59% Pervious Area
	0.270		79.41% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.0					**Direct Entry, Direct**

Summary for Pond 220P: P - Pond

Inflow Area = 5.334 ac, 77.24% Impervious, Inflow Depth = 3.57" for 25-year Storm event
Inflow = 4.78 cfs @ 7.90 hrs, Volume= 1.588 af
Outflow = 0.95 cfs @ 10.94 hrs, Volume= 1.356 af, Atten= 80%, Lag= 182.5 min
Primary = 0.95 cfs @ 10.94 hrs, Volume= 1.356 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-96.00 hrs, dt= 0.05 hrs / 3
Peak Elev= 254.64' @ 10.94 hrs Surf.Area= 9,539 sf Storage= 34,838 cf

Plug-Flow detention time= 1,396.3 min calculated for 1.356 af (85% of inflow)
Center-of-Mass det. time= 1,295.2 min (1,969.4 - 674.1)

Volume	Invert	Avail.Storage	Storage Description
#1	249.00'	45,213 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
249.00	3,256	0	0
250.00	4,194	3,725	3,725
251.00	5,185	4,690	8,415
252.00	6,264	5,725	14,139
253.00	7,430	6,847	20,986
254.00	8,685	8,058	29,044
255.00	10,028	9,357	38,400
255.65	10,934	6,813	45,213

Device	Routing	Invert	Outlet Devices
#1	Primary	247.00'	**12.0" Round Culvert** L= 100.0' RCP, square edge headwall, Ke= 0.500 Inlet / Outlet Invert= 247.00' / 245.00' S= 0.0200 '/' Cc= 0.900 n= 0.013, Flow Area= 0.79 sf
#2	Device 1	247.00'	**1.2" Vert. WQ Orifice** C= 0.600
#3	Device 1	254.50'	**6.0' long x 0.5' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 Coef. (English) 2.80 2.92 3.08 3.30 3.32
#4	Device 1	255.50'	**6.0' long x 0.5' breadth OF Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 Coef. (English) 2.80 2.92 3.08 3.30 3.32

Primary OutFlow Max=0.95 cfs @ 10.94 hrs HW=254.64' (Free Discharge)
└─**1=Culvert** (Passes 0.95 cfs of 8.60 cfs potential flow)
  ├─**2=WQ Orifice** (Orifice Controls 0.10 cfs @ 13.26 fps)
  ├─**3=Broad-Crested Rectangular Weir** (Weir Controls 0.84 cfs @ 1.03 fps)
  └─**4=OF Weir** (Controls 0.00 cfs)